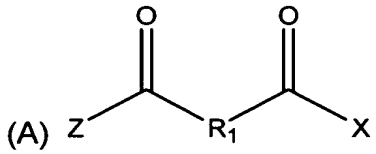
CLAIMS

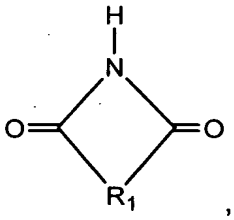
The invention claimed is:

1. A method of processing an initial compound having a formula (A)



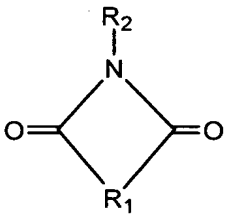
wherein R_1 comprises a saturated or unsaturated, branched or un-branched group containing from 1 to 10 carbon atoms, and wherein Z and X independently comprise one or more of C, H, O, N, S, a halide, and a counter-ion, the method comprising:

converting at least a portion of the initial compound to a second compound having a formula



the converting comprising one or both of thermal and catalytic processing;

reacting the second compound with an alkylating agent to form a derivative having a formula



wherein R_2 comprises an alkyl group, the derivative being present in a mixture comprising one or more additional components; and

performing a purification to remove at least some of the one or more

additional components.

2. The method of claim 1 wherein X and Z are independently selected from the group consisting of OR_3, OH, and O^- with a counter-ion, wherein R_3 comprises an alkyl group.

3. The method of claim 1 wherein the initial compound is selected from malic acid, maleic acid, fumaric acid, itaconic acid, succinamic acid, succinic acid or a derivative thereof.

4. The method of claim 1 wherein the alkylating agent comprises a member of the group consisting of an alcohol, a polyol, an acetal, a carboxylate, an alkyl halide, an alkyl amine, a carbonate compound, a thiol compound, a thiocarbonate compound, and a sulfate compound.

5. The method of claim 1 further comprising, prior to the converting, providing the initial compound in an aqueous solution.

6. The method of claim 1 wherein the initial compound is a diammonium salt.

7. The method of claim 1 wherein ammonia is added during the converting.

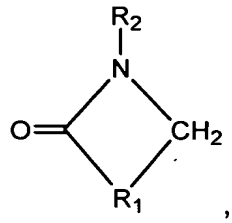
8. The method of claim 1 wherein ammonia is recovered during the converting, after the converting or both during and after the converting.

9. The method of claim 1 wherein the purification comprises at least one of decanting, distillation, sublimation, steam distillation, extraction and crystallization.

10. The method of claim 1 wherein the additional components comprise a reaction byproduct and wherein an additional amount of the derivative is produced from at least some of the reaction byproduct during the purification.

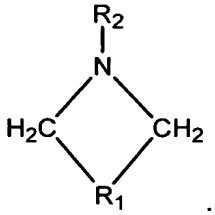
11. The method of claim 1 wherein the initial compound is selected from an ammonium succinate and diammonium succinate.

12. The method of claim 1 further comprising, after the purification, hydrogenating the derivative in the presence of a catalyst to produce at least one member of the group consisting of a product having formula (B)



(B) ,

and a product having formula (C)

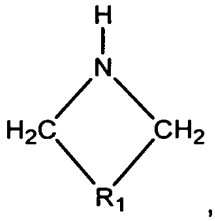


(C) .

13. The method of claim 12 wherein the hydrogenating is performed in the presence of added hydrogen.

14. The method of claim 12 wherein the hydrogenating produces the compound having the formula (B) and the compound having the formula (C), the method further comprising separation of the compound having formula (B) from the compound having formula (C).

15. The method of claim 12 wherein the method additionally produces one or both of a compound having formula (D)

(D) 

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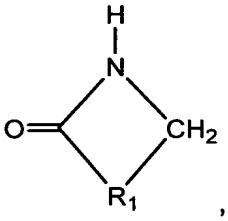
and a compound having formula (E)

(E) 

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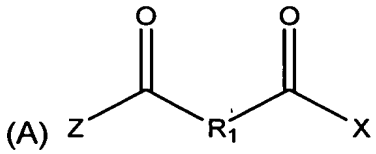
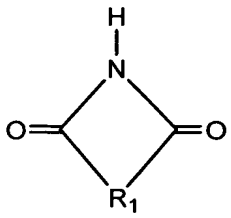
and further comprising separating the compound of formula (B) from the compounds having formulas (C), (D) and (E).

16. A method of processing an initial compound having a formula (A)

(A) 

wherein R_1 comprises a saturated or unsaturated, branched or un-branched group containing from 1 to 10 carbon atoms, and wherein Z and X independently comprise one or more of C, H, O, N, S, a halide, and a counter-ion, the method comprising:

converting the initial compound to a cyclic compound having a formula



the converting comprising one or both of thermal and catalytic processing, the cyclic compound being present in a mixture comprising one or more additional components; and

performing a purification to remove at least some of the one or more additional components.

17. The method of claim 16 wherein the converting and purification are conducted in a single reactor.

18. A method of producing an N-alkyl succinimide, the method comprising:

forming a solution comprising succinate, the forming comprising a fermentation process;

adding an alkylating agent to the solution;

in an absence of added hydrogen, converting at least some of the succinate to an N-alkyl succinimide.

19. The method of claim 18 wherein the alkylating agent comprises at least one of an alcohol, a glycol, a polyol, a carboxylate, an acetal, an epoxide, an aziridine, urea, a diol, an alkyl halide, an alkyl amine, a carbonate compound, a thiol compound, a thio-carbonate compound, and a sulfate compound.

20. The method of claim 18 wherein the alkylating agent is methanol.

21. The method of claim 18 wherein the N-alkyl succinimide is N-methyl succinimide.

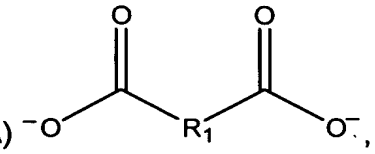
22. The method of claim 18 further comprising purifying the N-alkyl succinimide utilizing at least one of distillation, sublimation, decanting, steam distillation, extraction and crystallization.

23. The method of claim 18 wherein the converting is performed at a reaction temperature of from 100°C to 400°C.

24. The method of claim 23 further comprising cooling from the reaction temperature to below 100°C over a time period of less than or equal to about 30 minutes.

25. A method of making an N-alkyl product comprising:

providing an initial solution into a reactor, the solution comprising ammonia and an initial compound having formula (A);

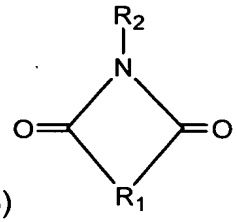
(A)  ,

where R_1 is selected from the group consisting of branched and un-branched hydrocarbons that are either saturated or unsaturated having from 1 to 10 carbons, the initial solution having a first ratio of ammonia to the initial compound;

adjusting the amount of ammonia to produce a solution having a second ratio of ammonia to initial compound of from about to 1:1 to about 1.5:1;

adding an alkylating agent to the reactor; and

cyclizing and alkylating the initial compound to produce an N-alkyl product having a formula (B)

(B) 

where R_2 is selected from linear, cyclic, branched, un-branched, saturated, unsaturated, aromatic, and substituted alkyl groups, and combinations thereof.

26. The method of claim 25 wherein the alkylating agent is methanol.

27. The method of claim 25 wherein the providing the initial solution comprises a fermentation process.

28. The method of claim 25 wherein the adjusting comprises removal of ammonia from the reactor.

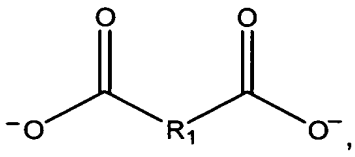
29. The method of claim 25 where the alkylating and cyclizing are conducted at a temperature of from greater than about 100°C to about 400°C.

30. The method of claim 25 further comprising at least partially purifying the N-alkyl product utilizing at least one of decanting, distillation, sublimation, reactive distillation, steam distillation, extraction and crystallization.

31. The method of claim 30 wherein the purification is conducted as the N-alkyl product is formed utilizing reactive distillation.

32. A method of producing a pyrrolidinone comprising:

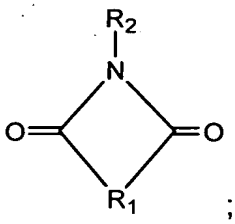
providing an initial solution into a first reactor, the solution comprising ammonia and comprising an initial compound having formula (A);

(A)  ,

where R_1 is selected from the group consisting of branched and un-branched hydrocarbons having from 1 to 10 carbons, the initial solution having a first ratio of ammonia to the initial compound;

adjusting the ratio of ammonia to produce a solution having a second ratio of ammonia relative to the initial compound of from 1:1 to 1.5:1;

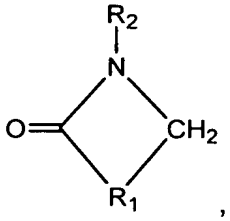
alkylating and cyclizing the initial compound to form a compound having the formula (B)

(B)  ;

performing a purification step to produce a purified form of compound (B);

providing the purified form of compound (B) to a second reactor; and

in the presence of a catalyst, hydrogenating the purified compound (B) to produce a pyrrolidinone compound having formula (C)

(C)  ,

where R_2 comprises an alkyl, a substituted alkyl group, or an aromatic group.

33. The method of claim 32 wherein the catalyst comprises at least one member selected from the group consisting of Fe, Ni, Pd, Sn, Pt, Co, Re, Rh, Ir, Os, Ag, Au, Ru, Zr, and Cu.

34. The method of claim 32 wherein the catalyst comprises rhodium.

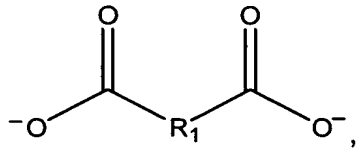
35. The method of claim 34 wherein the catalyst comprises a carbon support from about 0.5% to about 5% Rh, by weight.

36. The method of claim 34 wherein the catalyst comprises up to about 5% Rh by weight and wherein the Rh is edge-coated on the carbon support.

37. The method of claim 32 wherein the purified compound (B) is provided to the second reactor in solid or molten form and is hydrogenated in an absence of added solvent.

38. A method of producing a pyrrolidinone comprising:

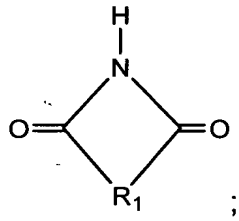
providing an initial solution into a first reactor, the solution comprising ammonia and comprising an initial compound having formula (A);

(A)  ,

where R_1 is selected from the group consisting of branched and un-branched hydrocarbons having from 1 to 10 carbons, the initial solution having a first ratio of ammonia to the initial compound;

adjusting the ratio of ammonia to produce a solution having a second ratio of ammonia relative to the initial compound of from 1:1 to 1.5:1;

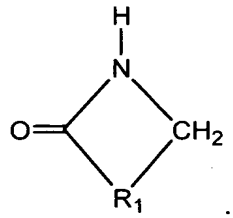
cyclizing the initial compound to form a compound having the formula (B)

(B)  ;

performing a purification step to produce a purified form of compound (B);

providing the purified form of compound (B) to a second reactor; and

in the presence of a catalyst, hydrogenating the purified compound (B) to produce a pyrrolidinone compound having formula (C)

(C)  .

39. A method of making N-methyl pyrrolidinone comprising:

forming an aqueous mixture comprising ammonia and succinate;

introducing the mixture into a vessel;

adjusting the amount of ammonia in the mixture to provide a ratio of ammonia to succinate of less than 2 to 1;

providing a methylating agent into the vessel;

reacting the methylating agent with the succinate at a temperature of from greater than about 100°C to about 400°C, the reacting producing N-methyl succinimide;

at least partially purifying the N-methyl succinimide;

after the at least partially purifying, hydrogenating the N-methyl succinimide to form a product mixture comprising N-methyl pyrrolidinone.

40. The method of claim 39 wherein the forming the aqueous mixture comprises:

conducting a fermentation process which produces succinate in a fermentation liquid; and

filtering the fermentation liquid to remove at least some cellular components.

41. The method of claim 40 wherein prior to the introducing the mixture into a vessel, the water content of the mixture is adjusted to be approximately equivalent to the amount of succinate present in the mixture, by weight.

42. The method of claim 39 wherein the product mixture further comprises 1 or more of 2-pyrrolidone, N-methyl pyrrolidine and pyrrolidine.

43. The method of claim 39 further comprising collecting the N-methyl pyrrolidinone, wherein the mole amount of N-methyl pyrrolidinone is greater than about 70% of an initial amount of succinate.

44. The method of claim 43 further comprising recycling one or more member of the group consisting of NH_3, H_2O, the methylating agent, and by-products produced during the reacting to produce N-methyl succinimide.